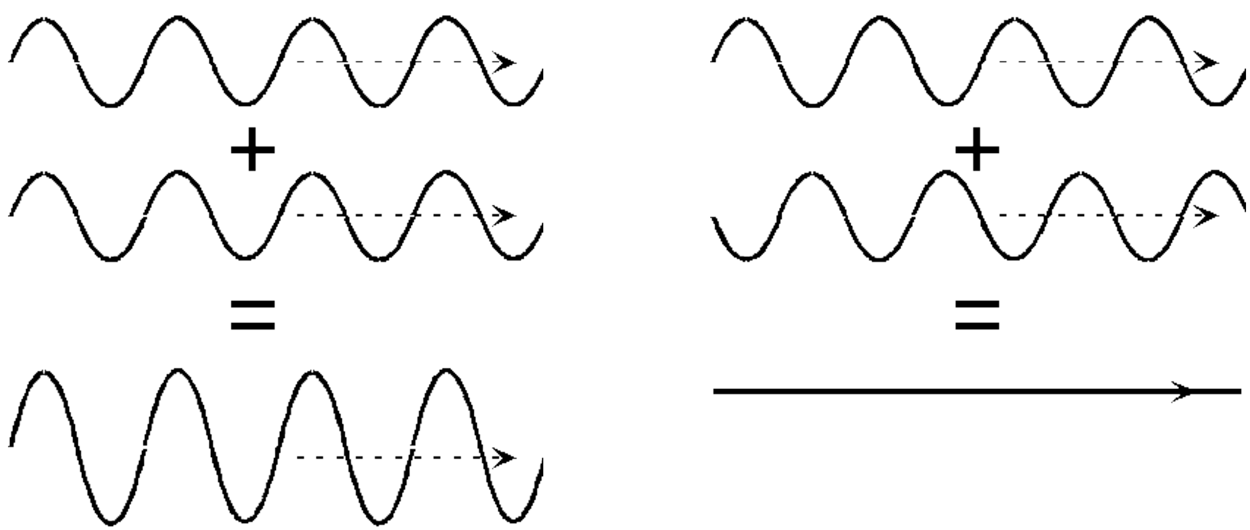
Wave model of Light

- Treat light as a classical electromagnetic wave
- Waves can add constructively or destructively



http://www.phys.uconn.edu/~gibson/Notes/Section5_2/Sec5_2.htm

Interference and Diffraction

- *All* interference and diffraction patterns
  - Locate the two waves that are interfering
  - Determine path difference *d*
  - Determine phase change φ
    - Constructive interference if φ is even multiple of π
    - Destructive interference if φ is odd multiple of π

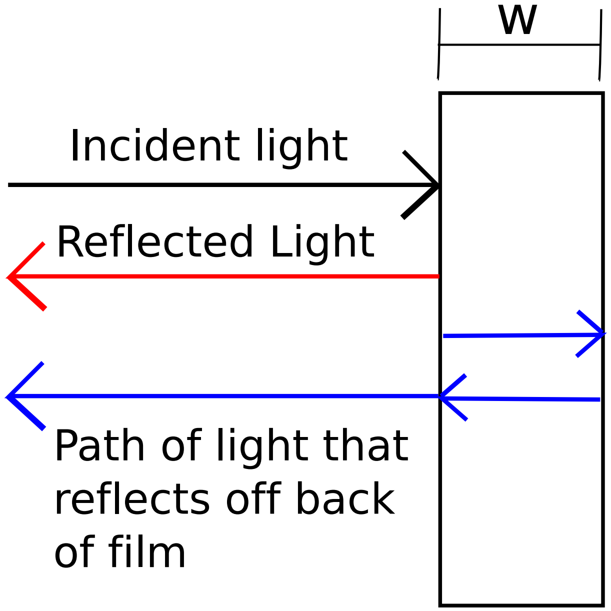
$$\frac{\phi}{2\pi} = \frac{d}{\lambda}$$

Interfaces

- Wave may pass between media with different indexes of refraction $n_{in} \neq n_{out}$
- What changes?
  - Wave speed? Frequency? Wavelength?
- Reflection at interfaces
  - For wave passing into a region with a **larger** n, the reflection may be inverted
  - Need to add π to the phase difference: $\varphi \rightarrow \varphi + \pi$

Thin Film Interference

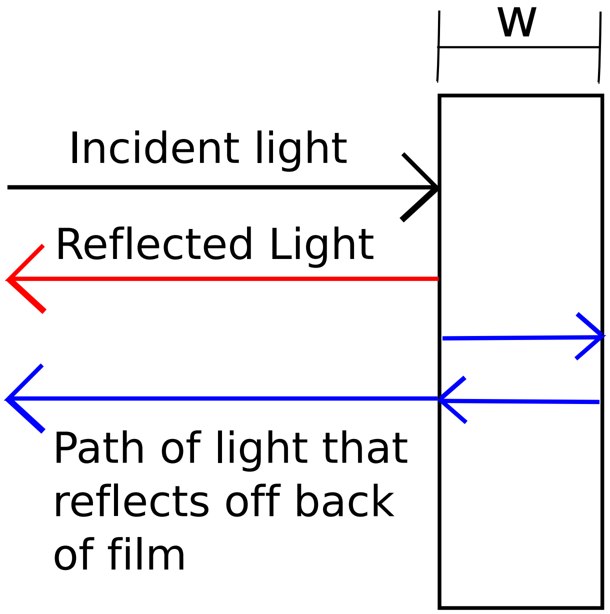
- Beam splits at first interface
- Impedance mismatch at front interface (phase shift)
- There may also be a second mismatch at the back interface
- Path difference is twice film thickness:
  - $d = 2w$
  - $(\varphi+\pi)/\ 2\pi\ = 2w/\lambda$



Thin Film Example

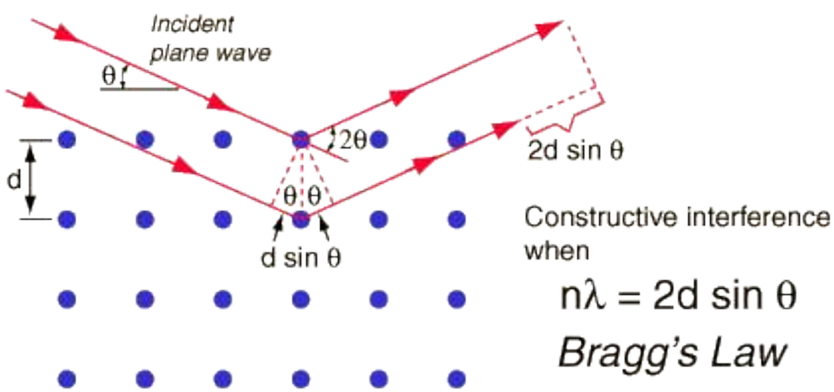
82. Consider two horizontal glass plates with a thin film of air between them. For what values of the thickness of the film of air will the film, as seen by reflected light, appear bright if it is illuminated normally from above by blue light of wavelength 488 nanometers?

(A) 0, 122 nm, 244 nm
(B) 0, 122 nm, 366 nm
(C) 0, 244 nm, 488 nm
(D) 122 nm, 244 nm, 366 nm
(E) 122 nm, 366 nm, 610 nm



Bragg Diffraction

- Incident light enters crystal and rebounds at an angle, forming distinct diffraction points
- Treat lattice planes of crystal as diffraction slits (or as thin film, at an angle)



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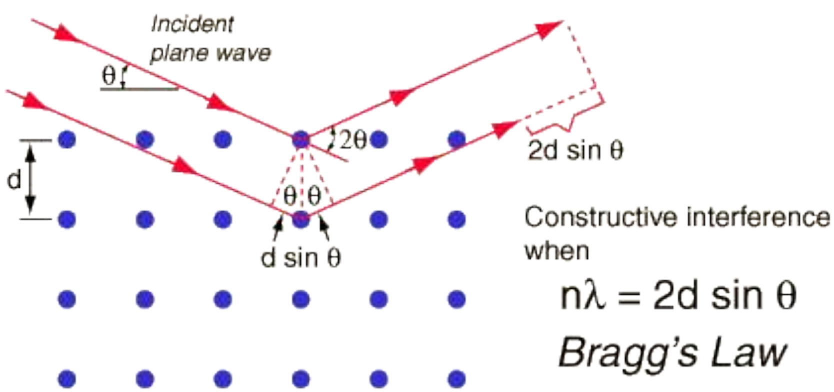
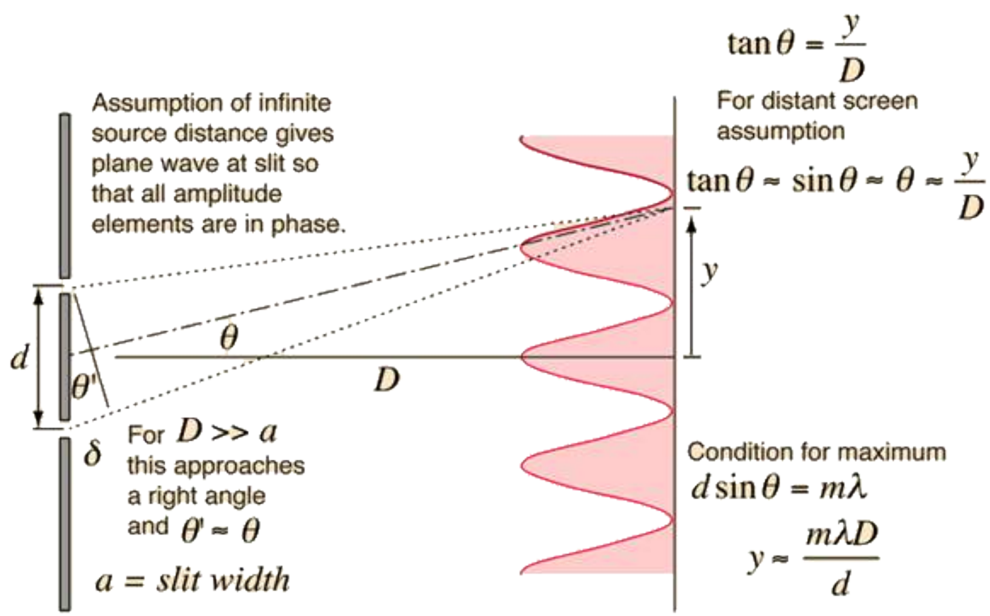


91. When a narrow beam of monoenergetic electrons impinges on the surface of a single metal crystal at an angle of 30 degrees with the plane of the surface, first-order reflection is observed. If the spacing of the reflecting crystal planes is known from x-ray measurements to be 3 ångstroms, the speed of the electrons is most nearly

(A) 1.4×10^{-4} m/s
(B) 2.4 m/s
(C) 5.0×10^{3} m/s
(D) 2.4×10^{6} m/s
(E) 4.5×10^{9} m/s

Double Slit Diffraction

- Path difference:
  - Look at difference between light passing through two slits
  - Condition on maxima becomes d sinθ = nλ



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http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

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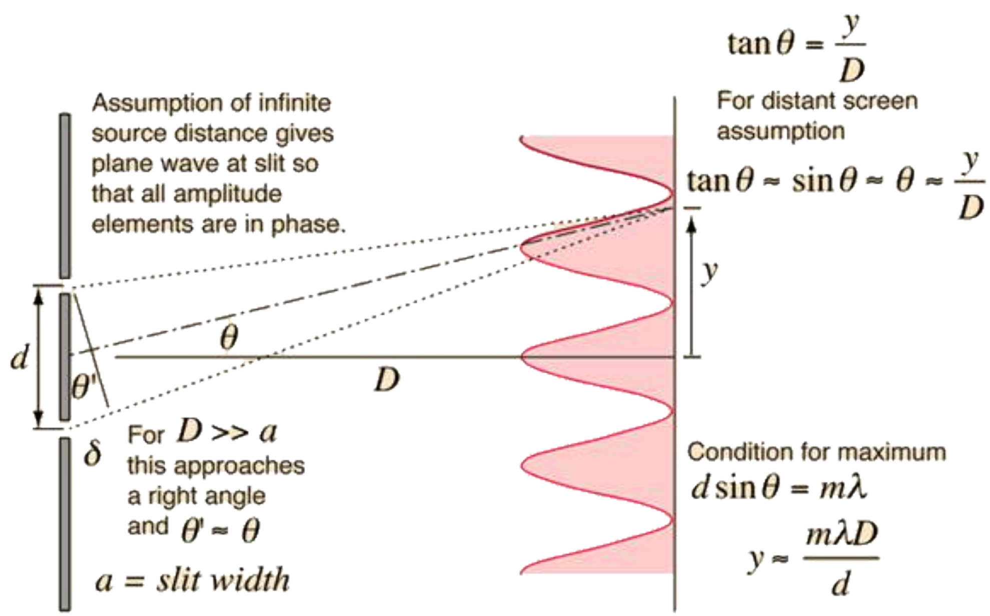

70. Light from a laser falls on a pair of very narrow slits separated by 0.5 micrometer, and bright fringes separated by 1.0 millimeter are observed on a distant screen. If the frequency of the laser light is doubled, what will be the separation of the bright fringes?

(A) 0.25 mm
(B) 0.5 mm
(C) 1.0 mm
(D) 2.0 mm
(E) 2.5 mm

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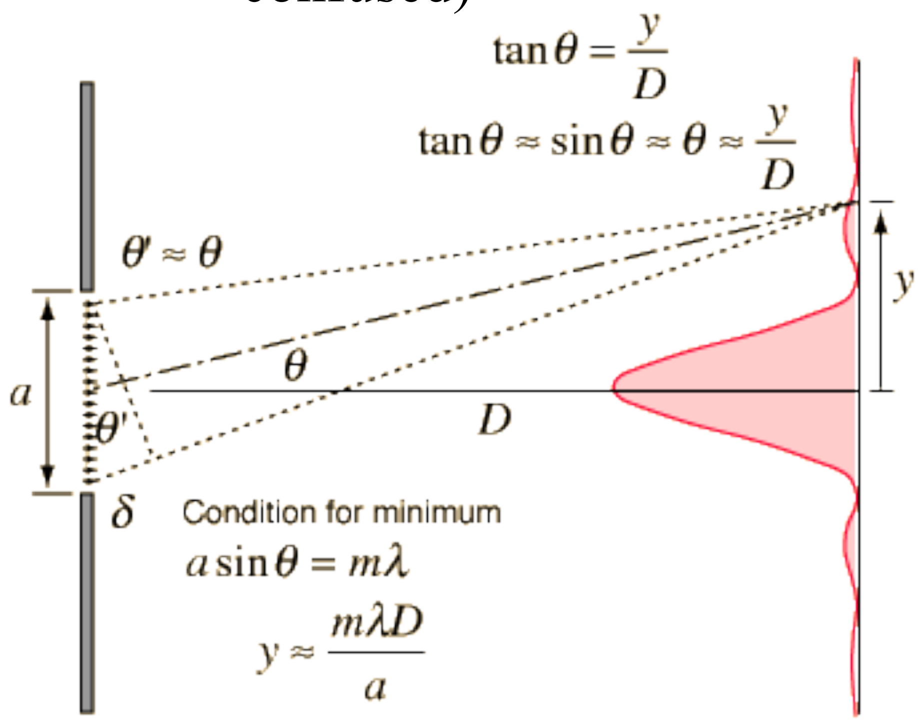
Single Slit Diffraction

- Derivation – divide slit into N very narrow slits and taking N to infinity
- Diffraction pattern goes as sin(θ)/(θ) with large central peak
  - Condition on **minima** becomes: a sinθ = mλ
  - Similar to double slit condition for maxima (easy to get confused)



57. Consider a single-slit diffraction pattern for a slit of width d. It is observed that for light of wavelength 400 nanometers, the angle between the first minimum and the central maximum is 4×10^{-3} radians. The value of d is

(A) 1×10^{-5} m

(B) 5×10^{-5} m

(C) 1×10^{-4} m

(D) 2×10^{-4} m

(E) 1×10^{-3} m

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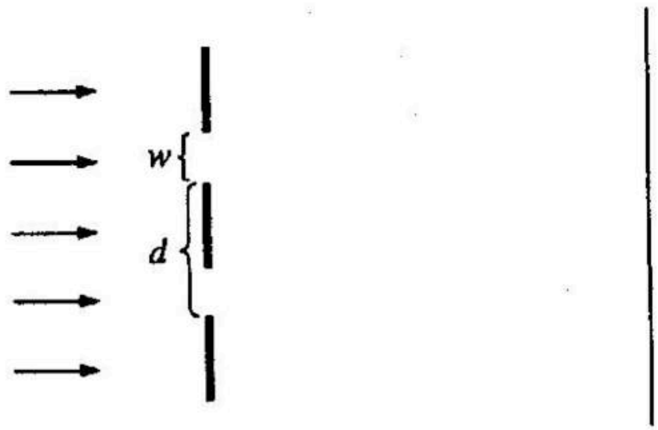
Diffraction as Fourier Transform

- Diffraction patterns are Fourier transforms of the object
  - FT[two dirac deltas] = sine wave
  - FT[step function] = sinc function
- In practice, double slit pattern with finite widths is the convolution of sinc and sine

Example: Diffraction Patterns



20. In a double-slit interference experiment, d is the distance between the centers of the slits and w is the width of each slit, as shown in the figure above. For incident plane waves, an interference maximum on a distant screen will be "missing" when

(A) $d = \sqrt{2}w$

(B) $d = \sqrt{3}w$

(C) $2d = w$

(D) $2d = 3w$

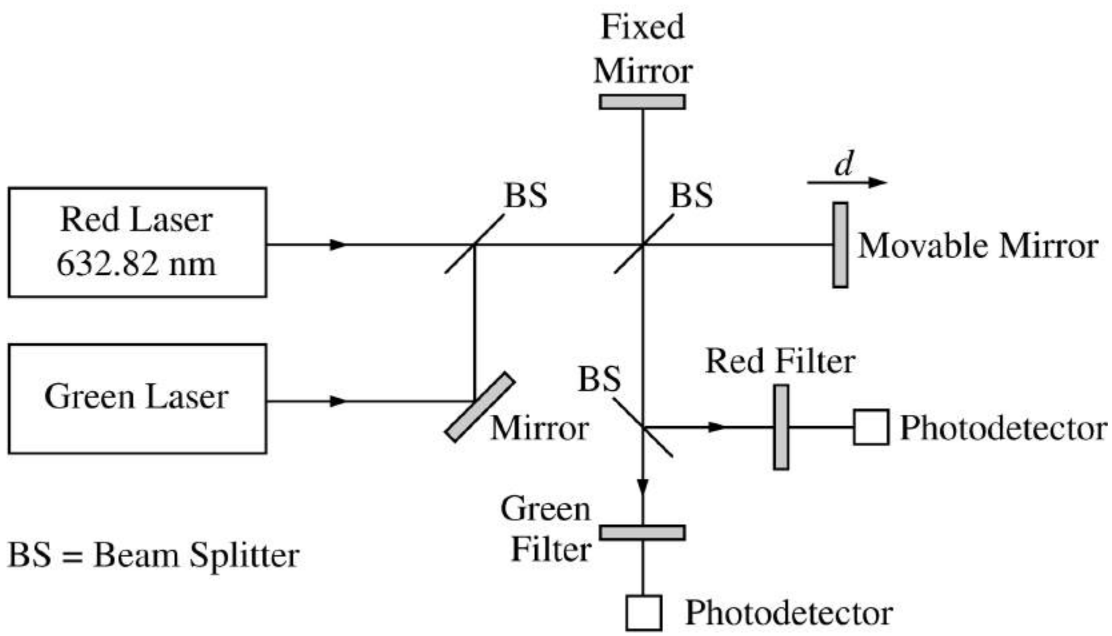
(E) $3d = 2w$

- When does a minimum from the single slit cancel out a maximum from the double slit?
- Single-slit condition for minimum is same as double-slit condition for maximum

$$\frac{sin(\theta)}{\lambda} = \frac{m}{w} = \frac{n}{d}$$

- Which answers are plausible?

Interferometry

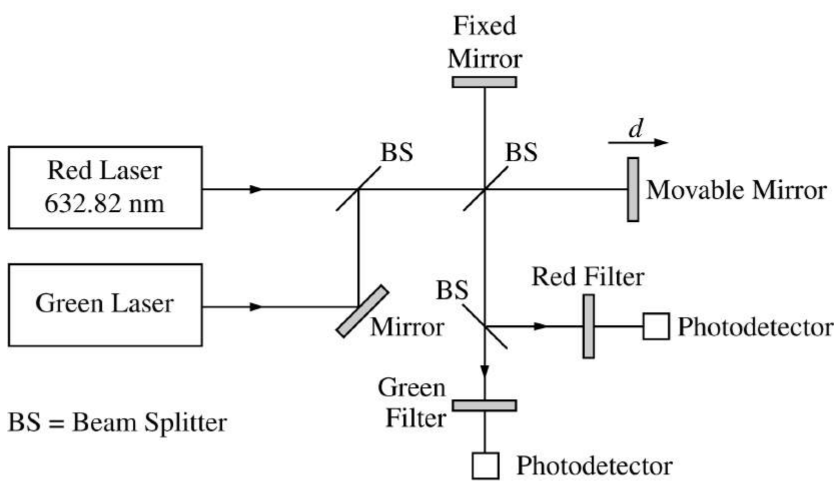


100. A Michelson interferometer is configured as a wavemeter, as shown in the figure above, so that a ratio of fringe counts may be used to compare the wavelengths of two lasers with high precision. When the mirror in the right arm of the interferometer is translated through a distance d, 100,000 interference fringes pass across the detector for green light and 85,865 fringes pass across the detector for red ($\lambda = 632.82$ nanometers) light. The wavelength of the green laser light is

(A) 500.33 nm
(B) 543.37 nm
(C) 590.19 nm
(D) 736.99 nm
(E) 858.65 nm

Interferometry

- Each fringe represents constructive interference
- Occurs when change in path length equals integer number of wavelengths
- In this case: $2d = m\lambda$ for each color of light



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